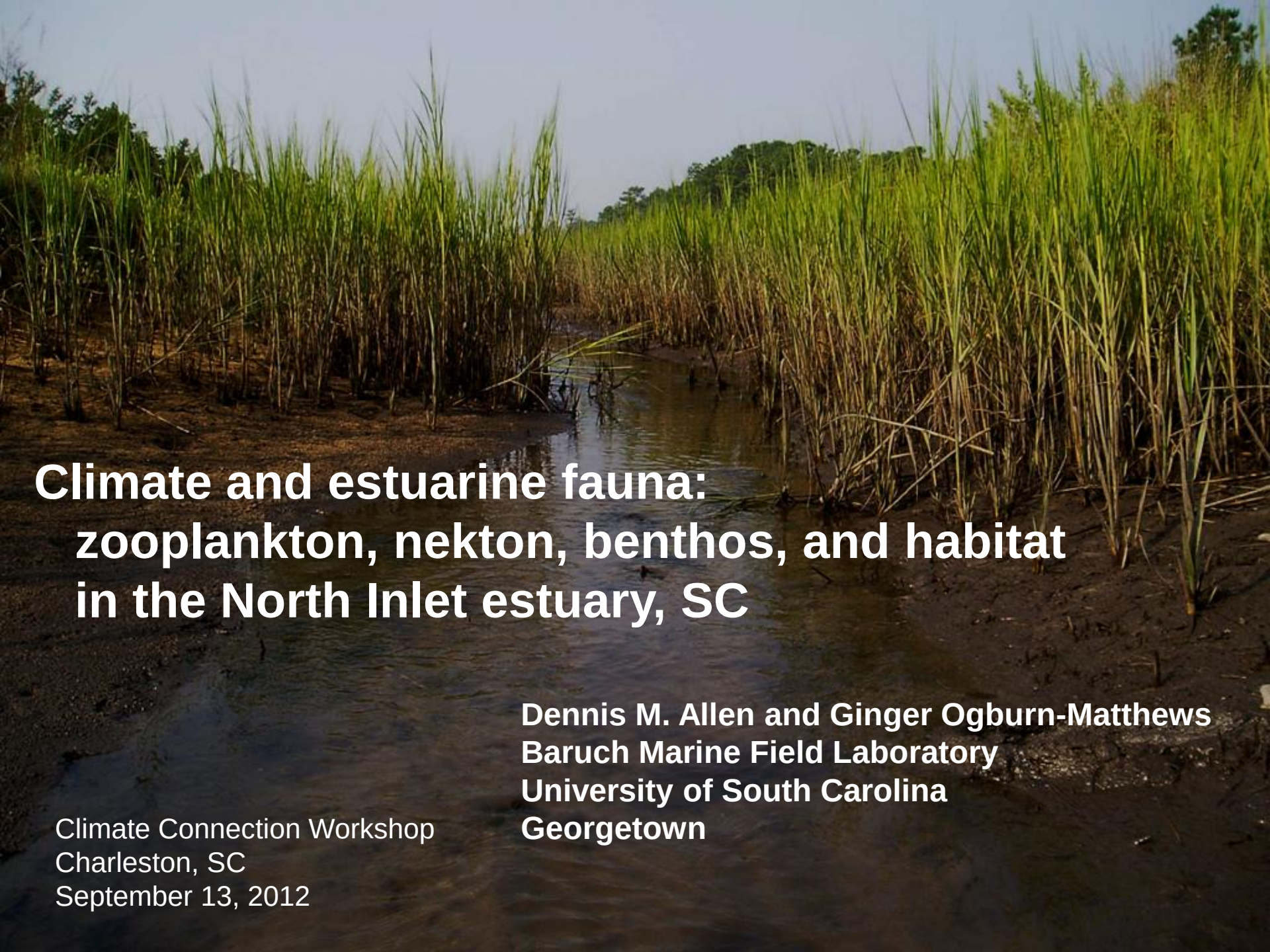
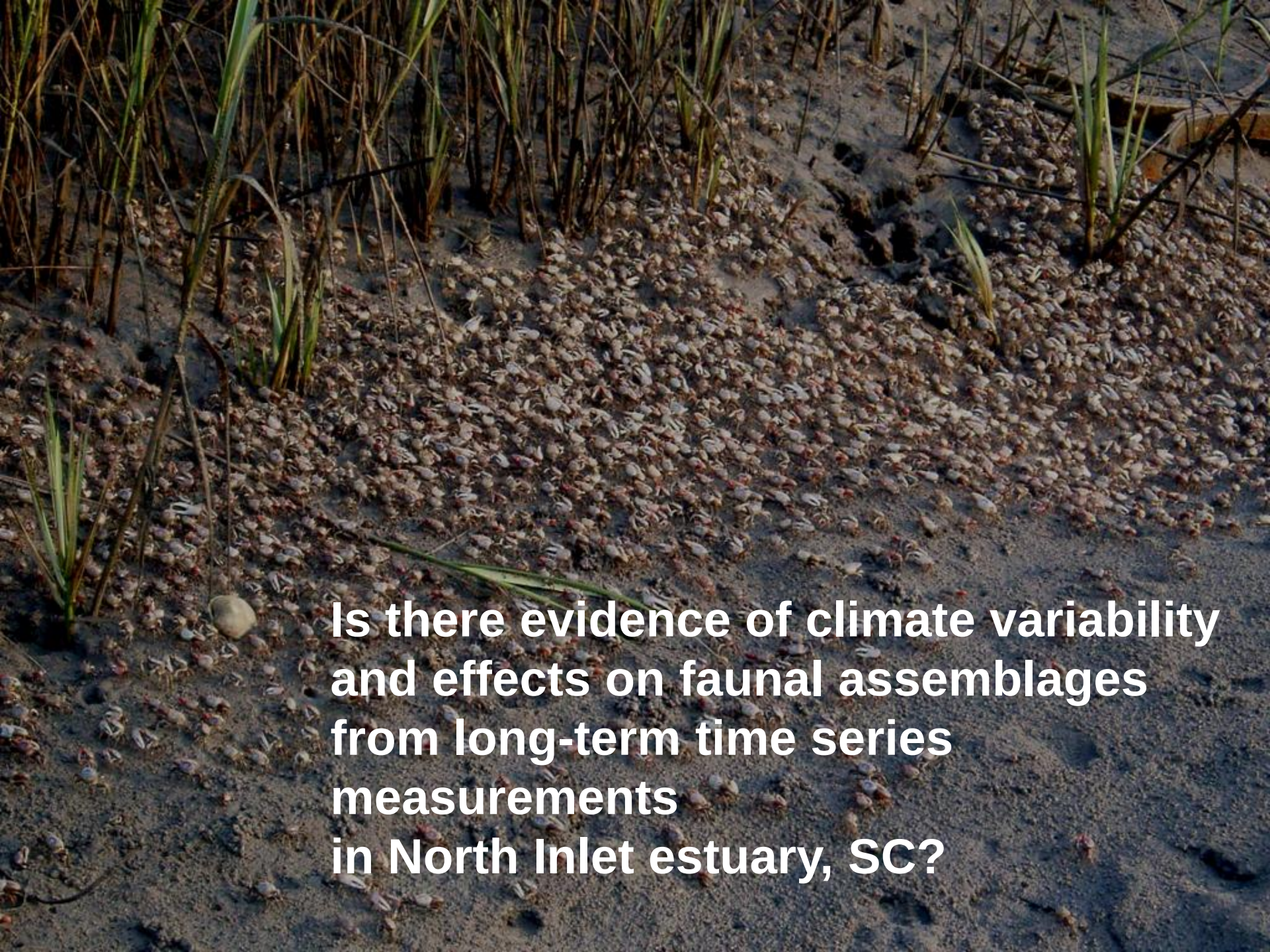


Climate and estuarine fauna: zooplankton, nekton, benthos, and habitat in the North Inlet estuary, SC

Dennis M. Allen and Ginger Ogburn-Matthews
Baruch Marine Field Laboratory
University of South Carolina
Georgetown

Climate Connection Workshop
Charleston, SC
September 13, 2012



Is there evidence of climate variability and effects on faunal assemblages from long-term time series measurements in North Inlet estuary, SC?

Baruch Marine Field Laboratory and the North Inlet - Winyah Bay
National Estuarine Research Reserve
University of South Carolina, Georgetown

BMFL

on Hobcaw Barony

North Inlet Estuary

- ocean dominated
- salt marsh and creeks
- relatively pristine

Winyah Bay Estuary

- river dominated
- open water, marsh fringe

Long-term time series from North Inlet estuary, SC:

Water Quality 1978 – present

- Water temperature
- Salinity / conductivity
- Dissolved oxygen
- Turbidity, pH
- Water level (tides)

Meteorological 1982 – present

- Air temperature
- Wind direction and speed
- Barometric pressure
- Solar radiation (PAR and short-wave)
- Rain, relative humidity

Water Chemistry 1978 - present

- Nitrogen (total whole, total filtered, particulate, ammonia, nitrate-nitrite)
- Phosphorus (total whole, total filtered, particulate, orthophosphate)
- Suspended sediment (total, inorganic, organic)
- Organic carbon (total, dissolved, particulate)
- Chlorophyll a

Biological

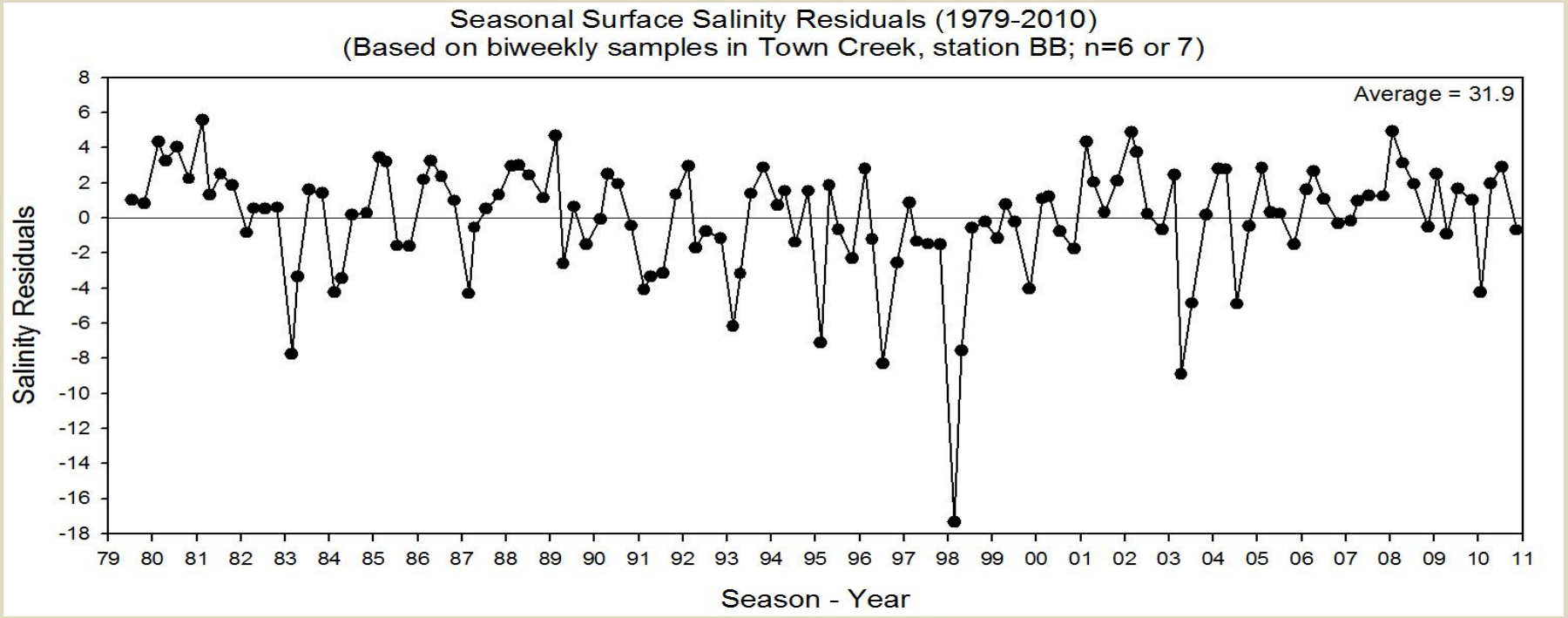
- Zooplankton (153 & 365 micron) 1981 - present
- Macrobenthos 1981 - present & Meiobenthos 1974-1998
- Nekton (fish, shrimp, & crab) 1984 - present
- *Spartina alterniflora* (marsh grass) 1984 - present

Other

- Marsh elevation (SET) & soil chemistry
- Harmful algae
- Marsh geomorphology & groundwater dynamics
- River discharge

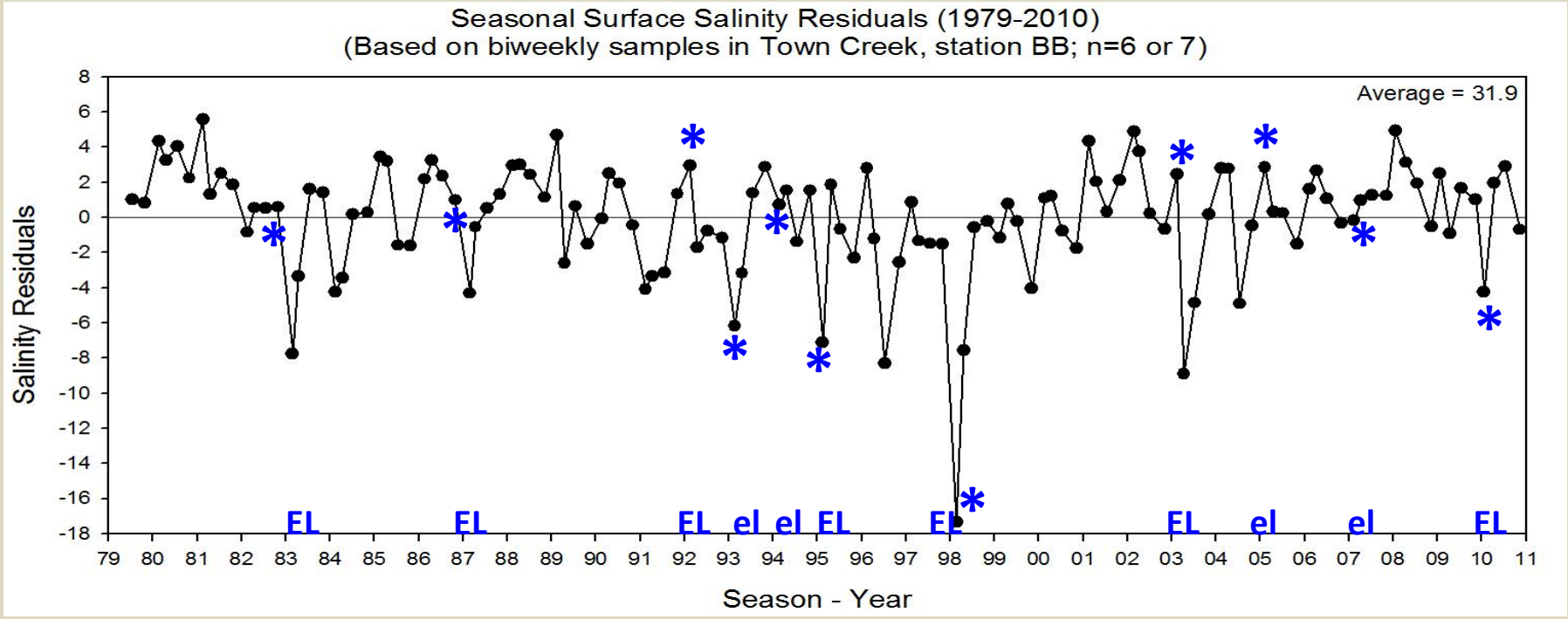
Salinity
North Inlet estuary, SC Town Creek, 1979-2010

no long-term trend, long-term average: 31.9 psu



Salinity and timing of El Nino events
North Inlet estuary, SC Town Creek, 1979-2010

no long-term trend, long-term average: 31.9 psu



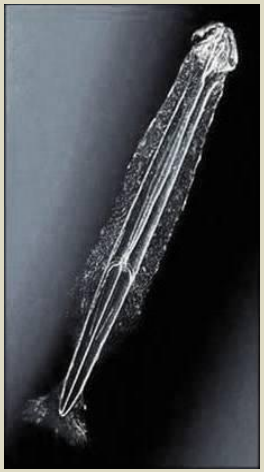
Winter- spring El Nino events:
stronger the event
greater the rainfall
lower the salinity

EL = strong El Nino
el = weak/short EL

Large mesozooplankton 1981 - 2012

- **biweekly replicated tows with an epibenthic sled, 365 micron mesh**
- **diverse assemblage of zooplankton, 28 counting categories**
- **1.6 to 20 mm in length**

holoplankton = full time members

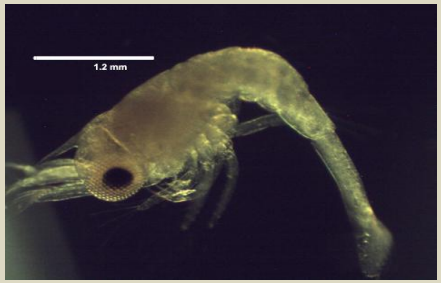


chaetognaths

amphipods

mysids

meroplankton = temporary members



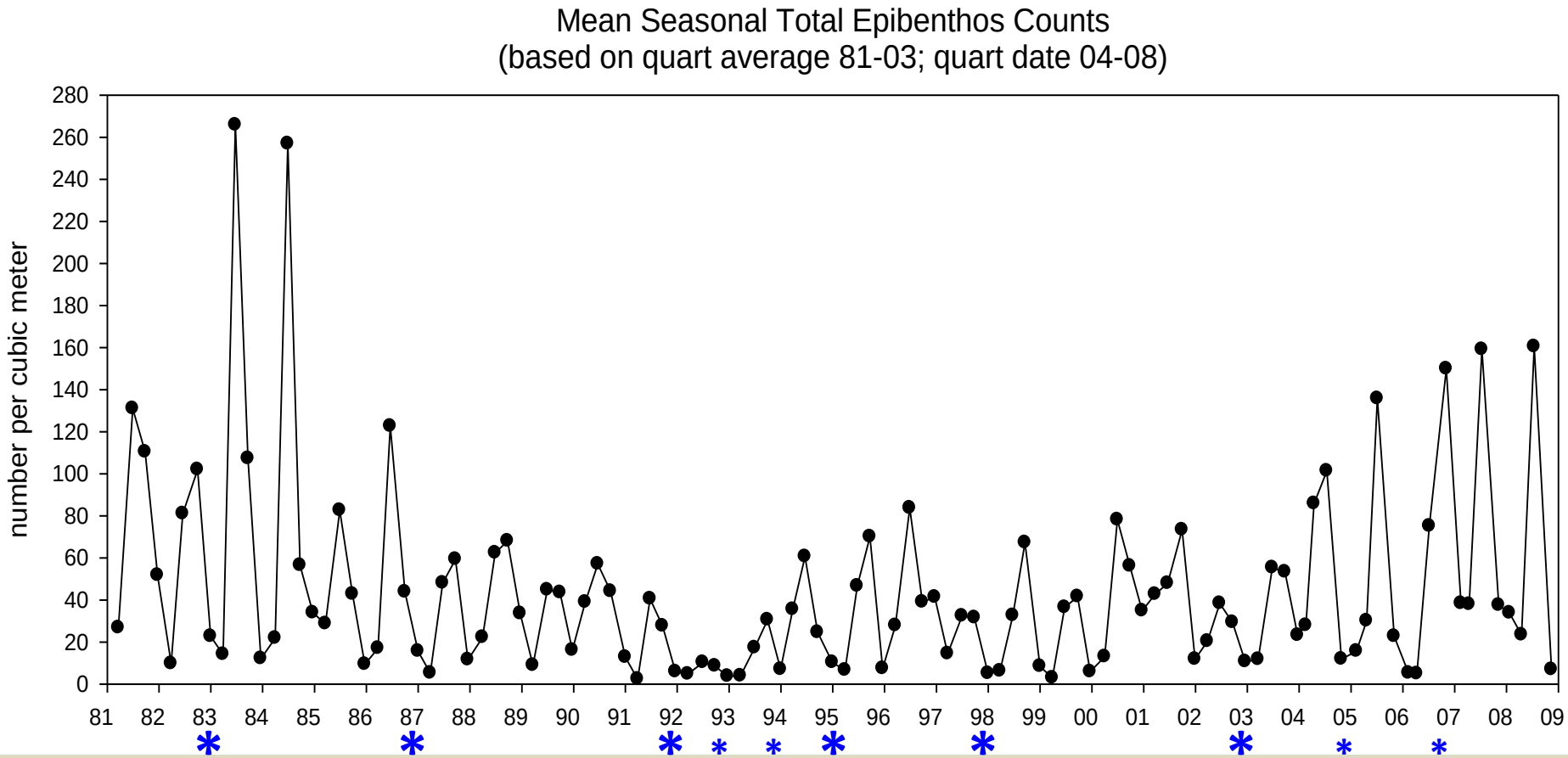
shrimp larvae

crab megalopae

fish larvae

LARGE mesozooplankton (365 micron)
North Inlet estuary, SC 1981-2008

no long- term trend, lowest densities in the 1990's
significant correlation with salinity r = 0.45 p = 0.01



Allen, et al. 2008. J. Coastal Research 55

Small mesozooplankton 1981 - 2012

- **biweekly, replicated, stepped vertical hauls, 153 micron mesh**
- **diverse assemblage, 17 counting categories**
- **0.5 to 2 mm in length**

holoplankton = full time members

copepods

hydromedusae

meroplankton = temporary members

crab zoeae

barnacle cyprid

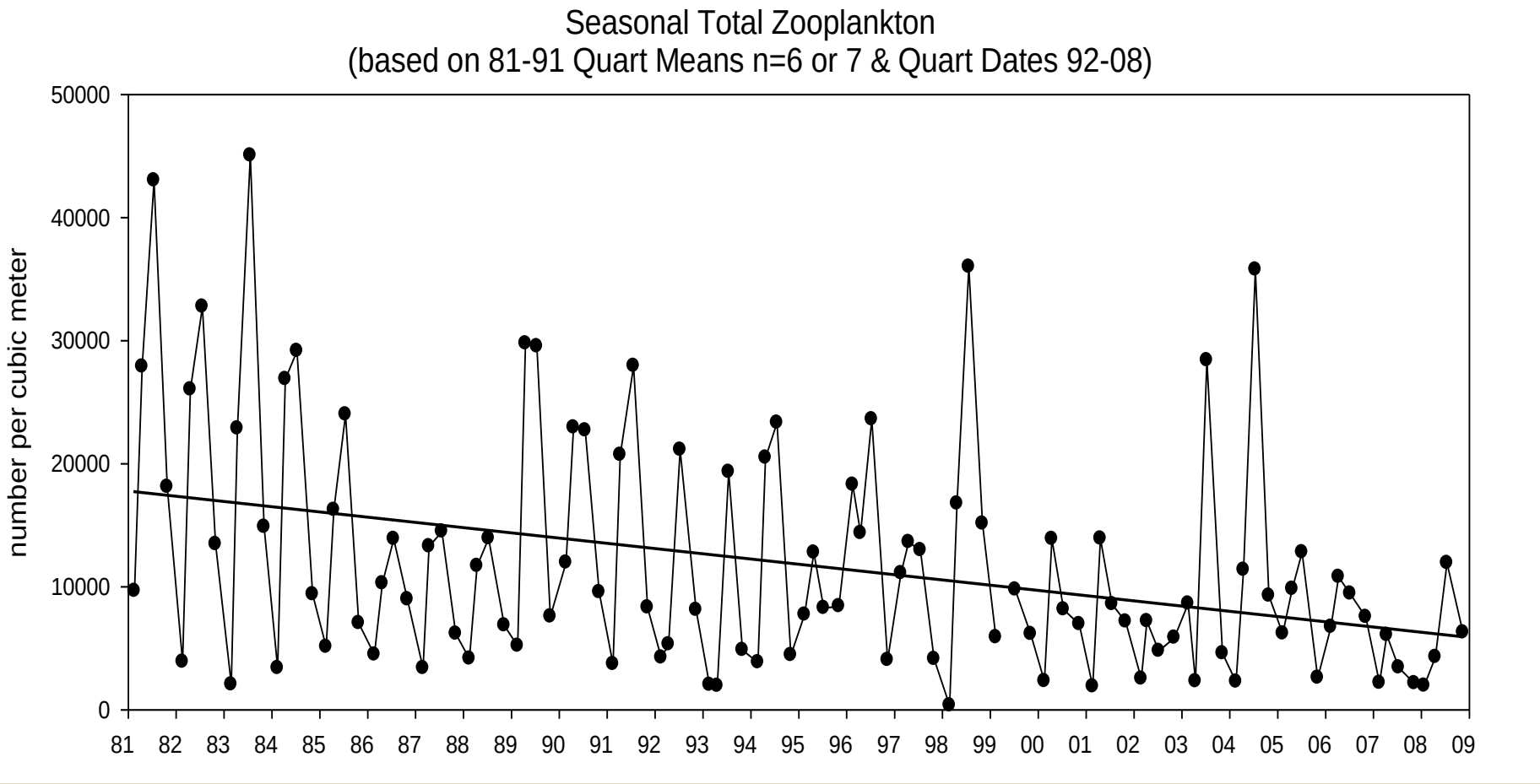
polychaete larvae

tunicate larvae

SMALL mesozooplankton (153 micron, copepods+small invert.larvae) North Inlet estuary, SC 1981 -2008

long-term decrease for total small zpk: r = -0.42, p = 0.0001

long-term decreases were observed for 16 of the 17 taxa

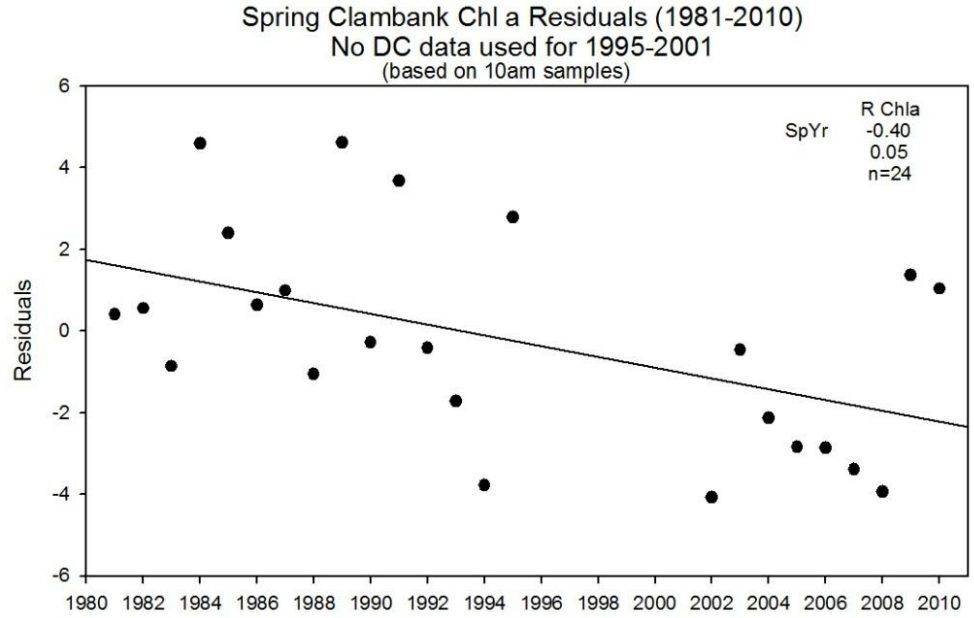


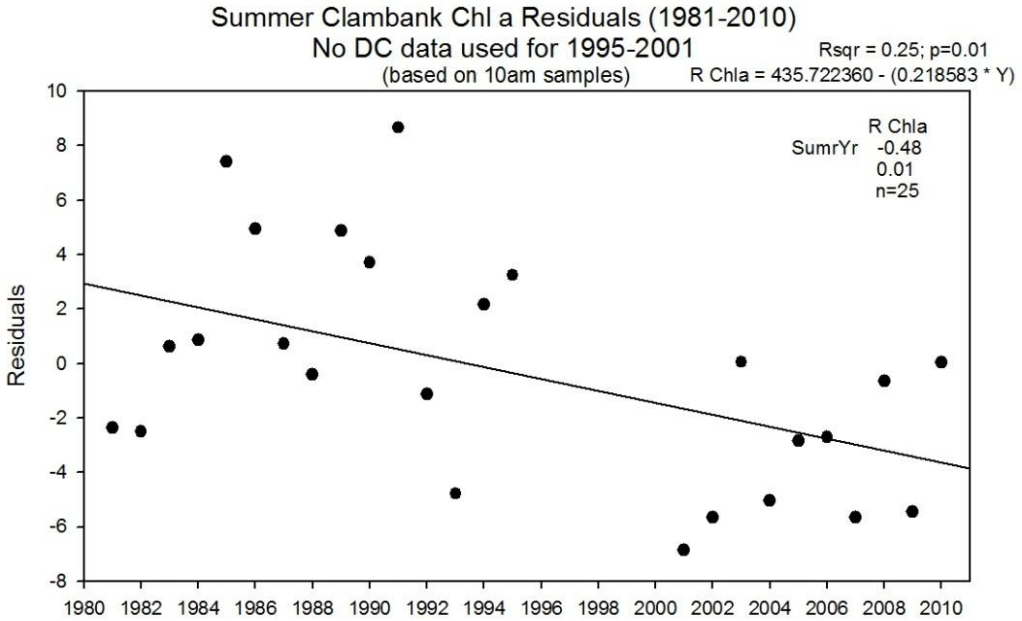
Chlorophyll a long-term trends

Spring
r = - 0.40, p = 0.05

Summer
r = - 0.48, p= 0.01

small zooplankton abundance is correlated with chlorophyll concentration r = 0.29 p = 0.005



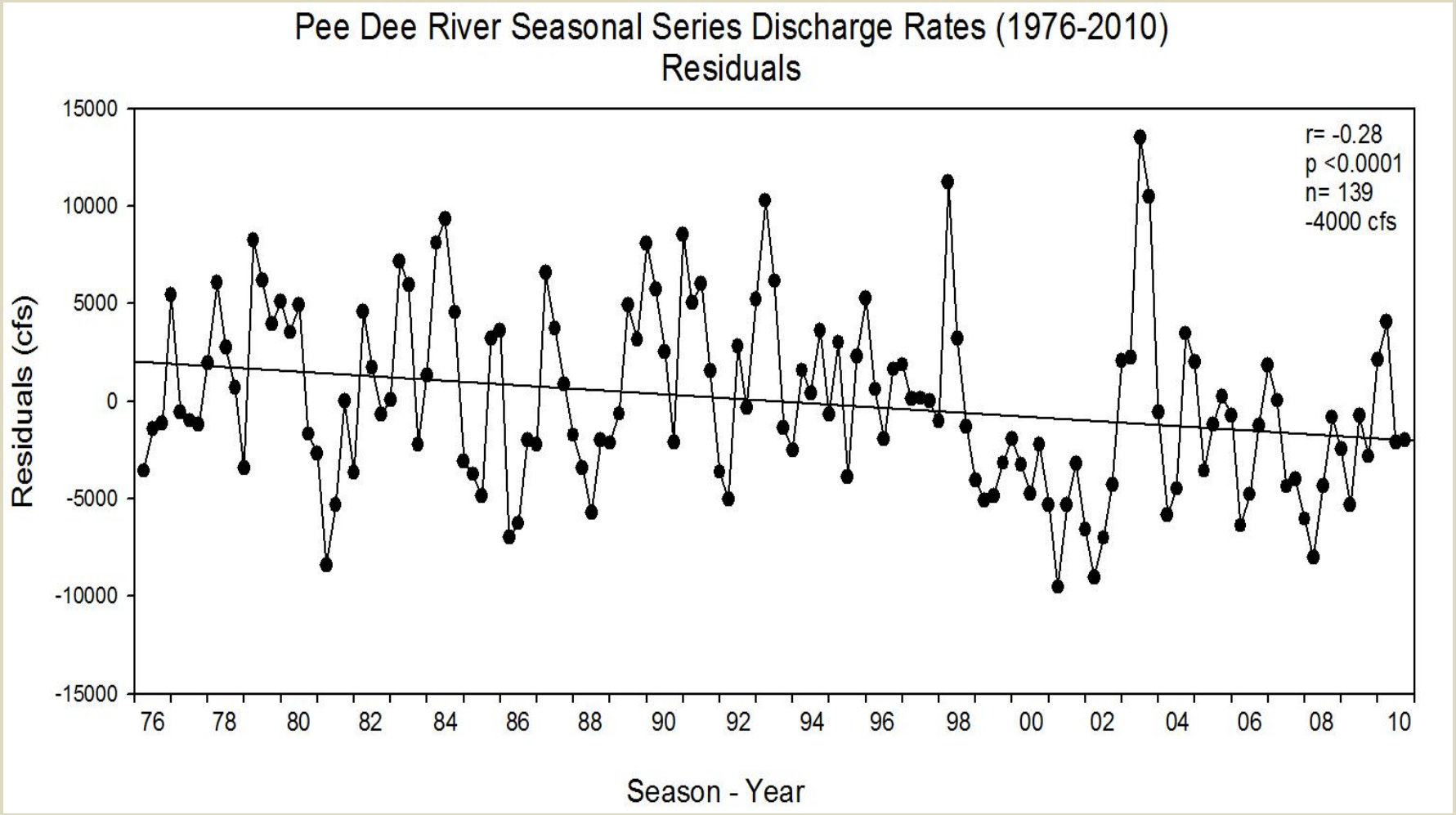


81-93 10am Bwk Chla Values from date of fauna cruise
93-10 20da 10am nutrient chemistry
95-01 no data collection; 06-09 used corrected data from Erik

Pee Dee River discharge rates 1976 – 2010

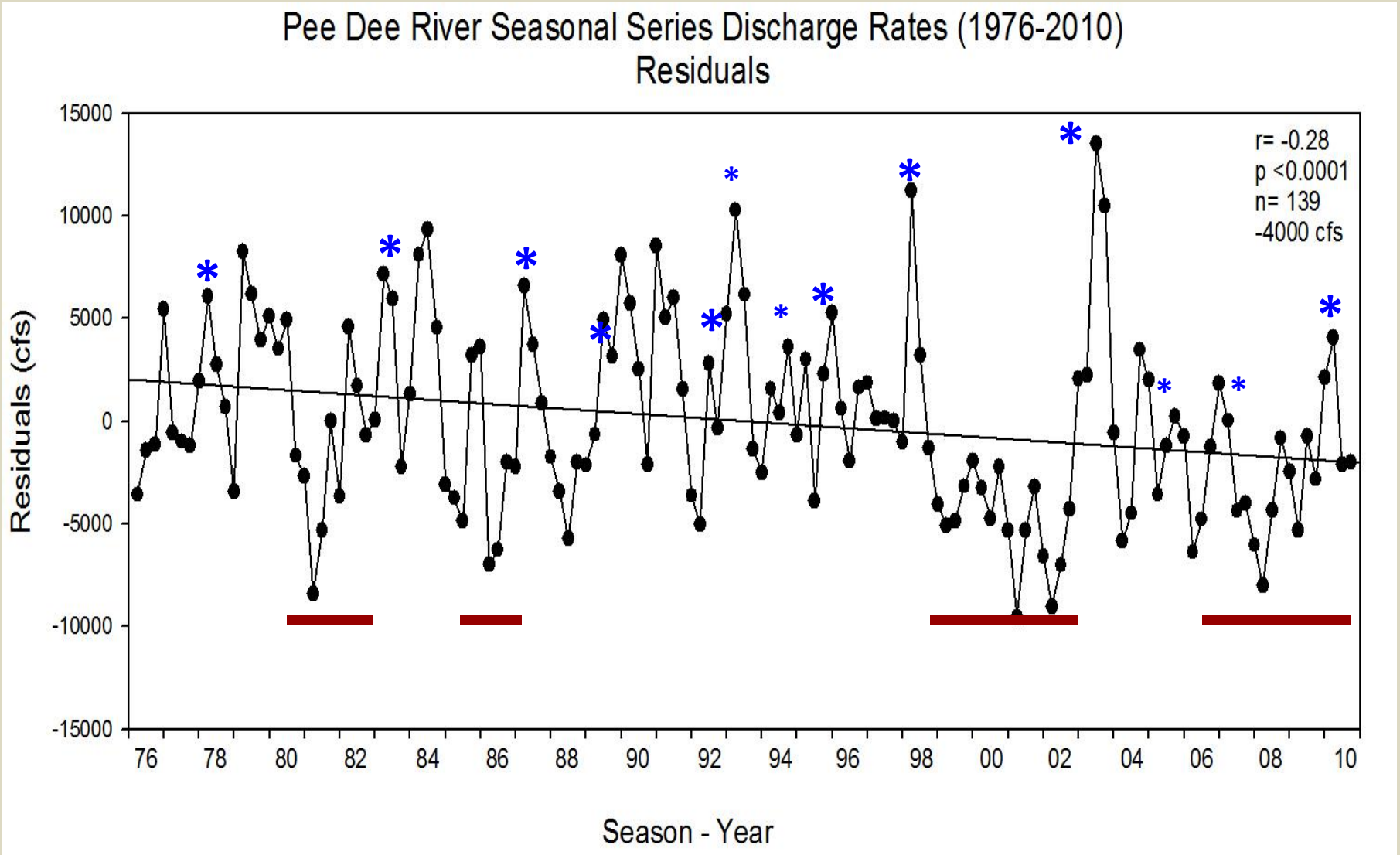
Decreasing long-term trend r = - 0.28, p< 0.0001

Reduction by about 4000 cfs or about 35% over the past 35 years



Pee Dee River discharge rates into Winyah Bay 1976 – 2010

high flow years correspond to El Nino * events
low flow years were during droughts



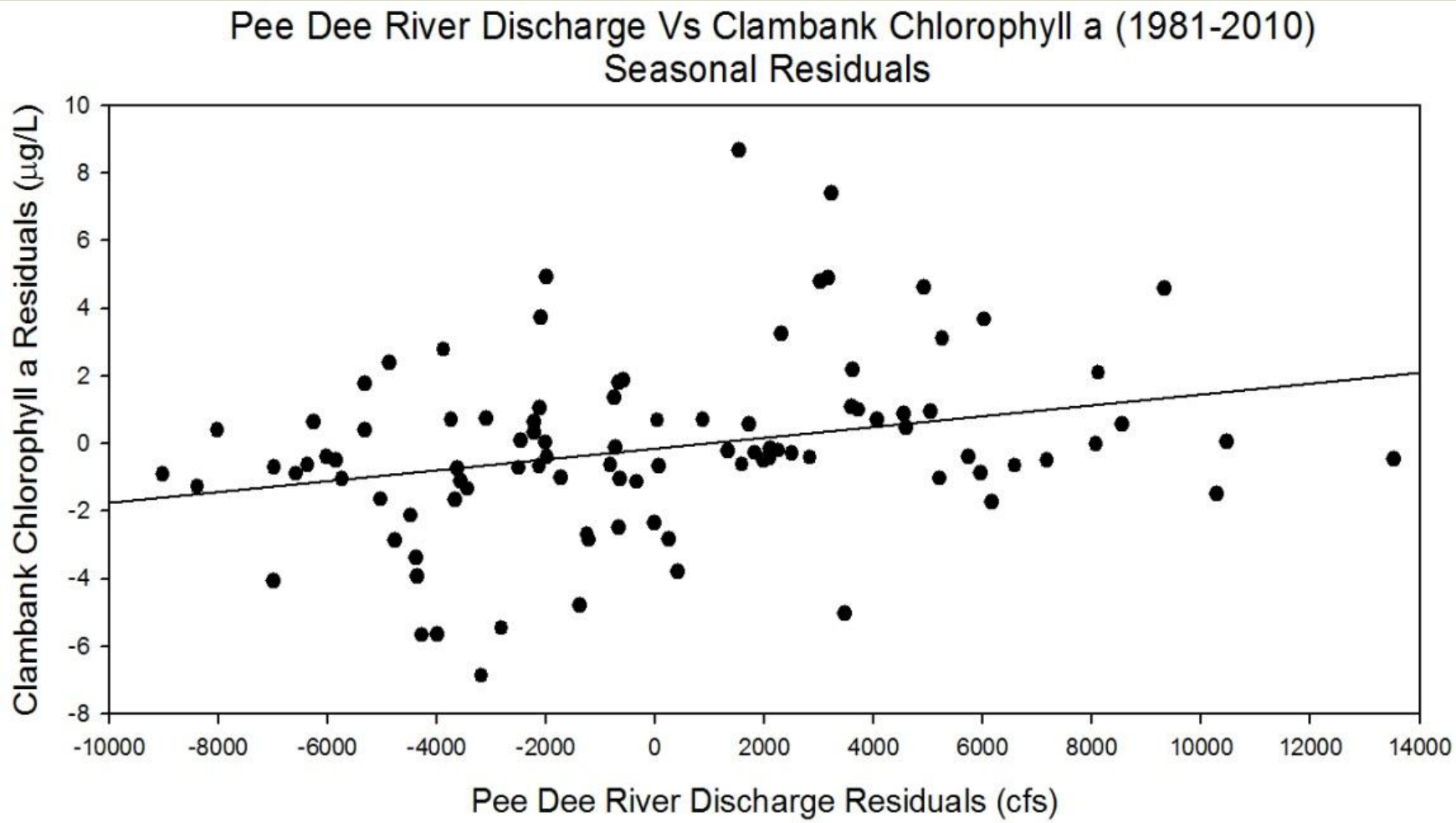
North Inlet Estuary

long-term zooplankton sampling site

Winyah Bay Estuary

River discharges increase
nutrient levels in the coastal ocean

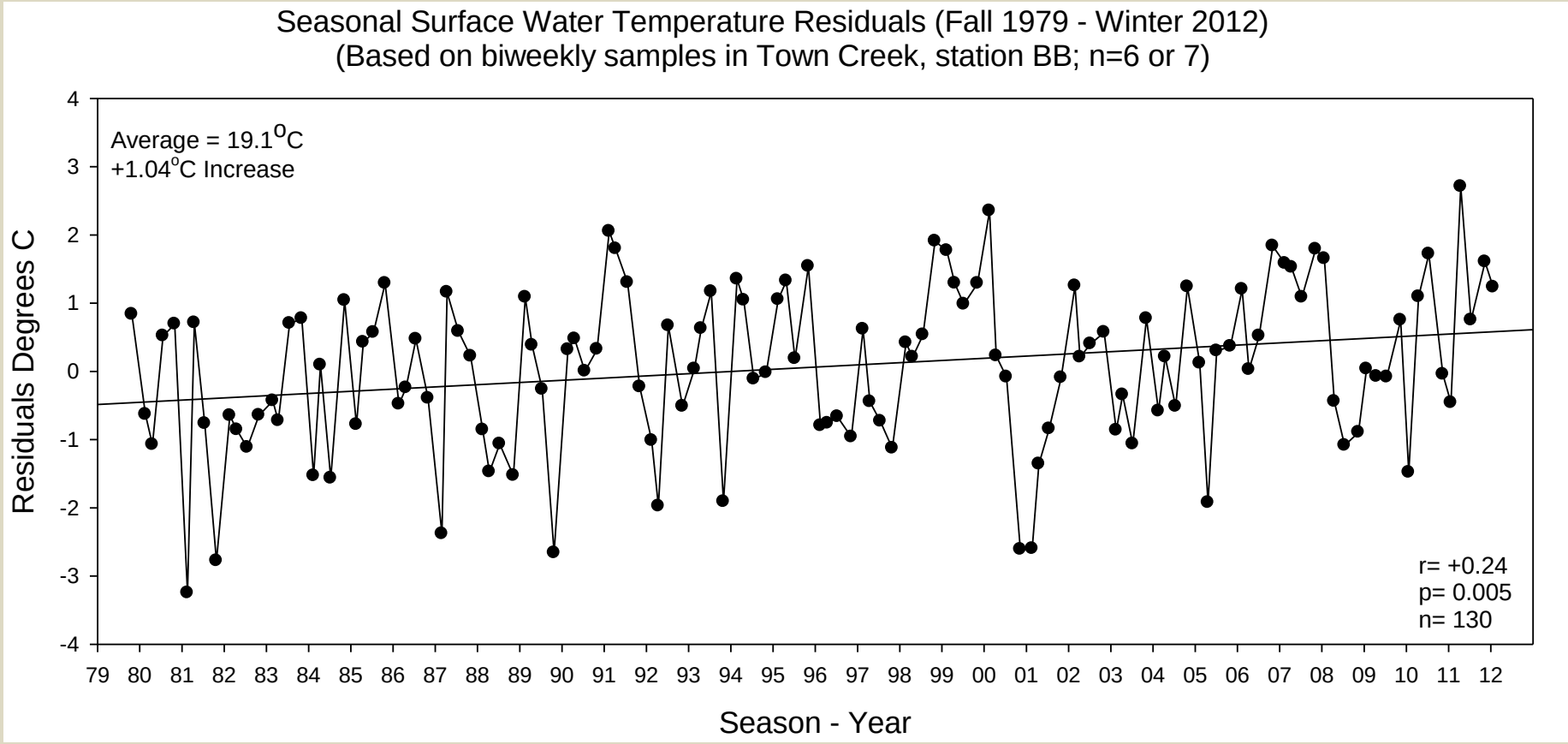
Pee Dee River discharge is correlated with chlorophyll concentrations in North Inlet estuary
r = 0.33 p = 0. 001



Water temperature at Town Creek, North Inlet, SC 1979 – 2012

Long-term increase: r = 0.24, p = 0.005

estimated change: +1.0 ºC

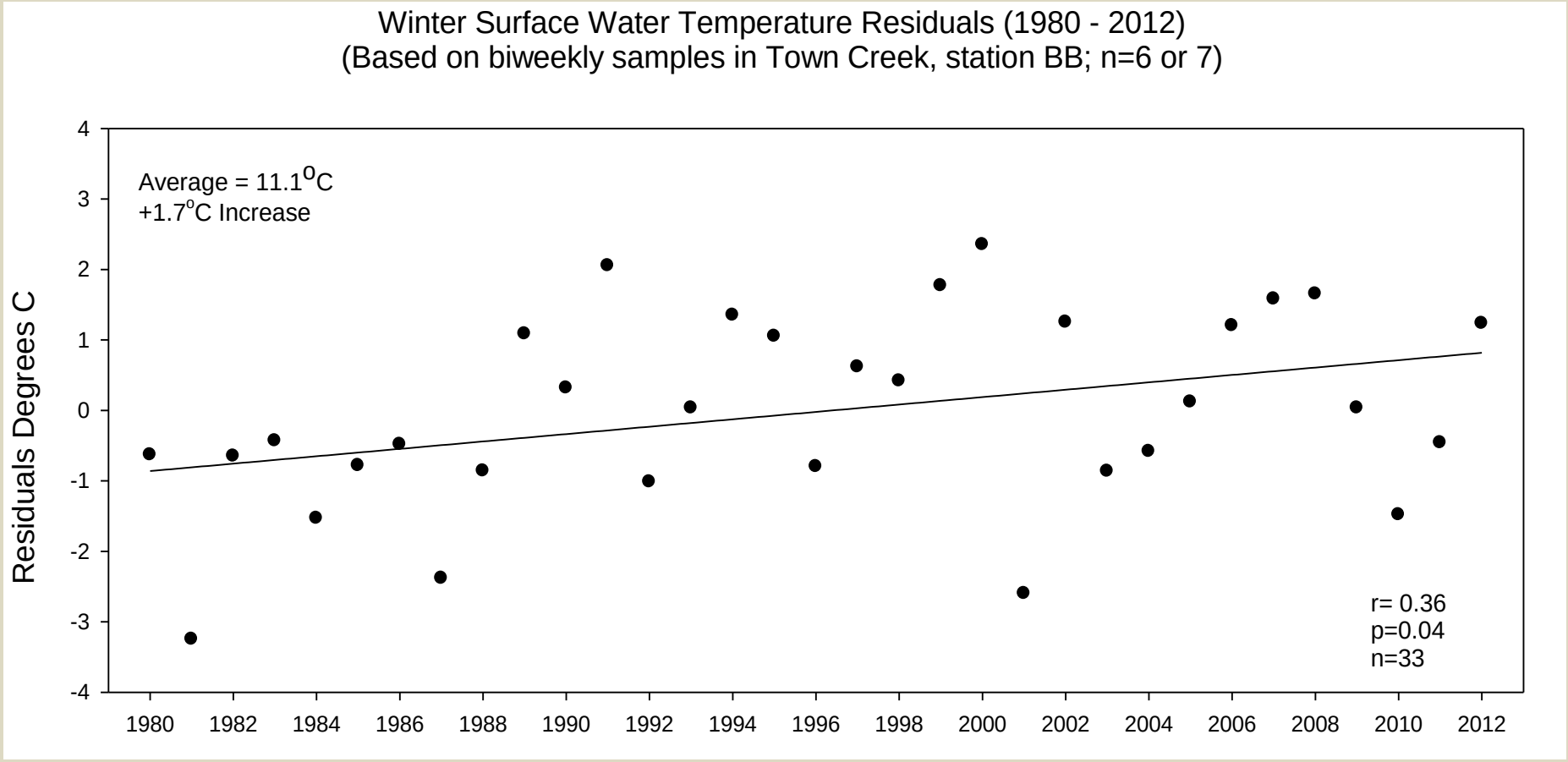


Deviations from long-term seasonal means

Winter water temperature at North Inlet estuary, SC 1980 – 2012

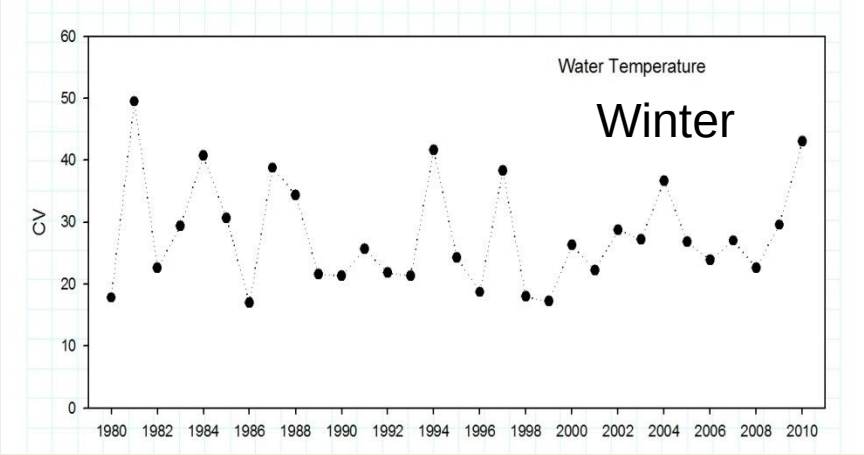
Long-term increase: r = 0.36, p = 0.04

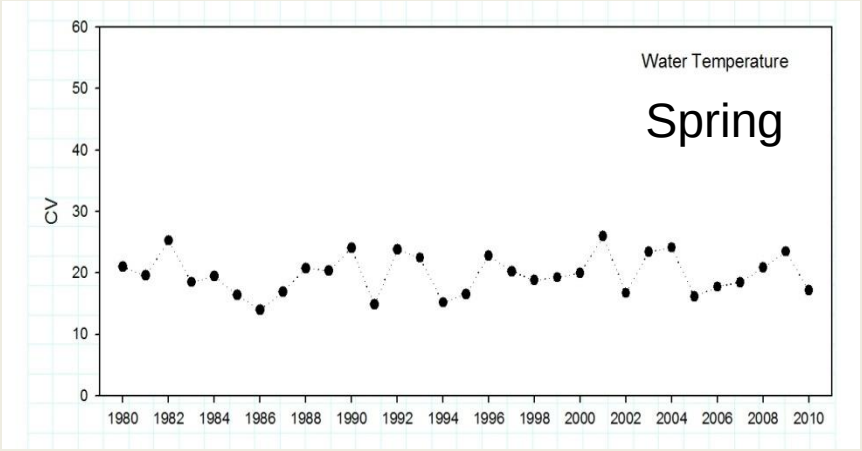
estimated change: +1.7° C

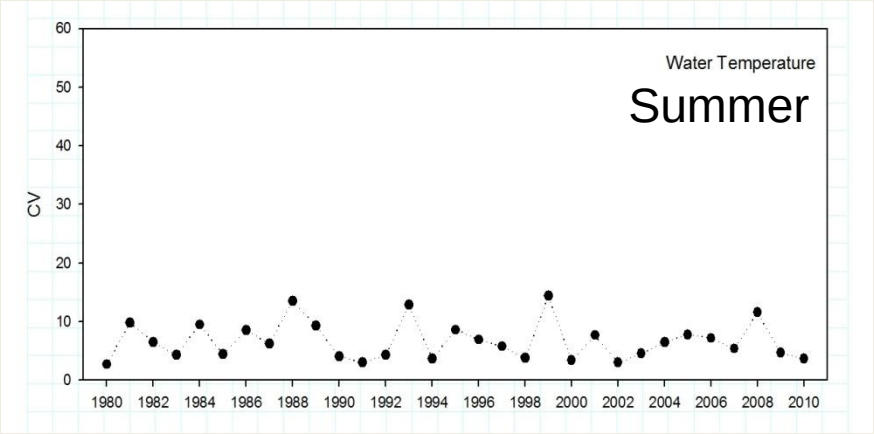


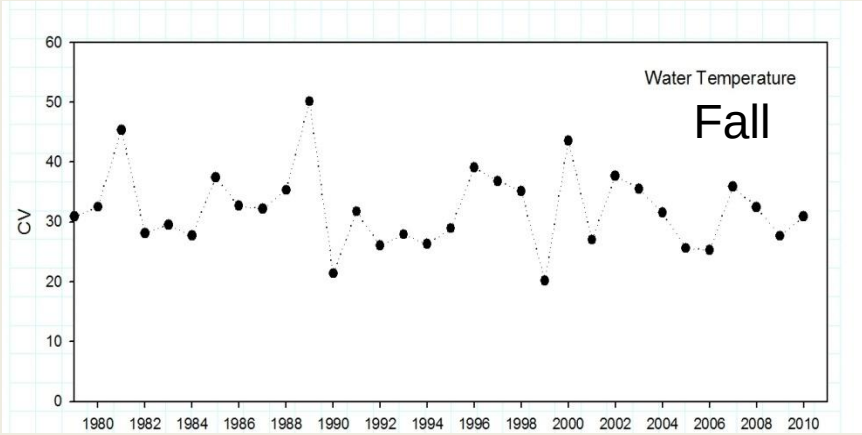
Winter water temperature correlated with winter NAO index, r= 0.60. p= 0.002

Water temperature: 1980 -2010
within year variability (coefficient of variation) for each season









Phenology = the study of natural recurring biological phenomena

Phenological changes in biota are usually related to interannual and long-term changes in temperature regimes.

Best known examples of phenological changes are from terrestrial systems:
- shifts in timing of migrations, egg laying, hatching of insects, birds
- changes in periods of plant flowering

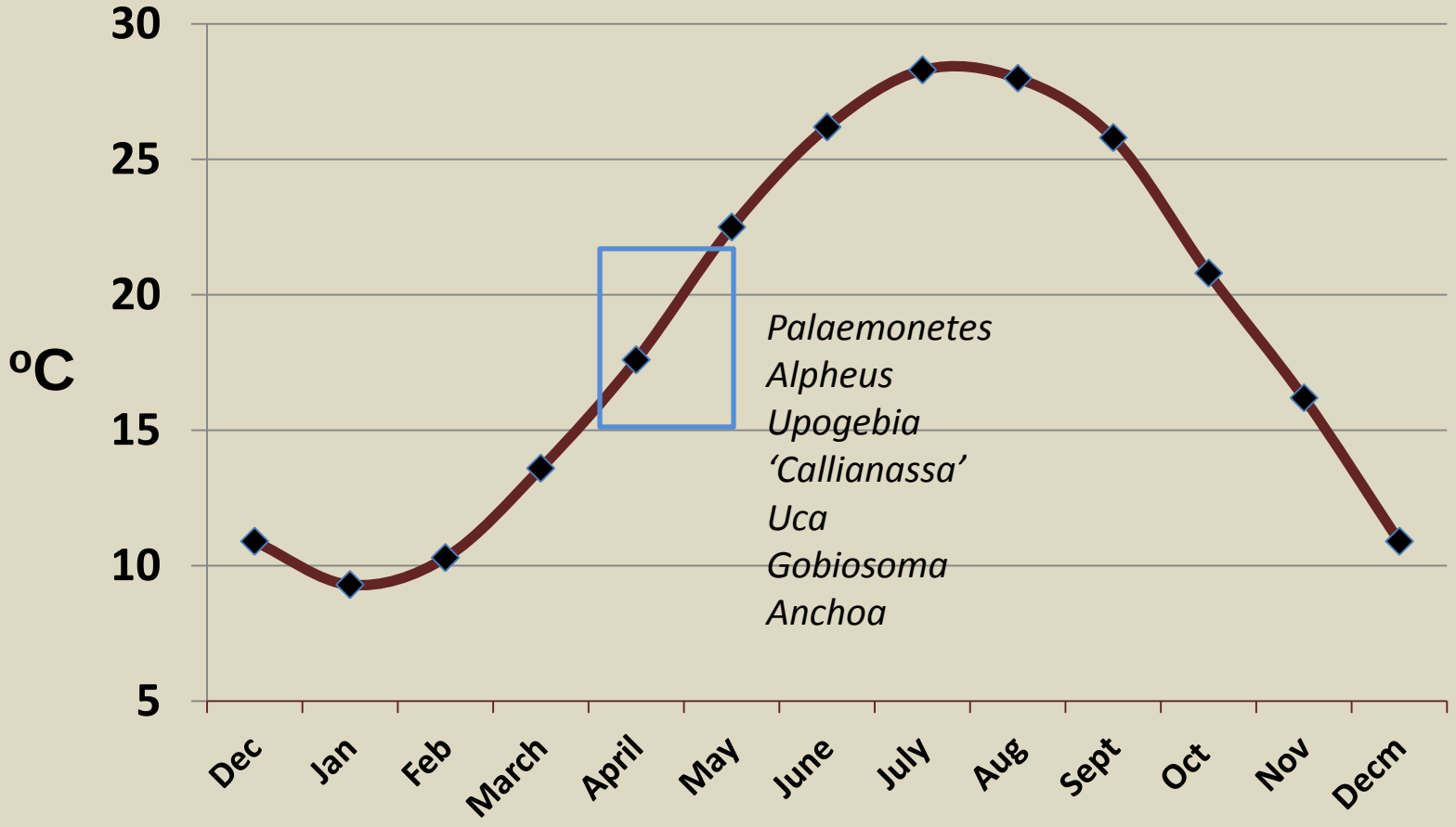
Examples from marine ecosystems are changes in the:
- timing of spring phytoplankton bloom
- peaks of copepods or gelatinous predators
- first occurrence of decapod crustacean larvae

Almost all reports are from mid- and high latitude ocean areas

Few reports from estuaries, none from the Southeast?

Mean monthly water temperature for the period 1981-2010

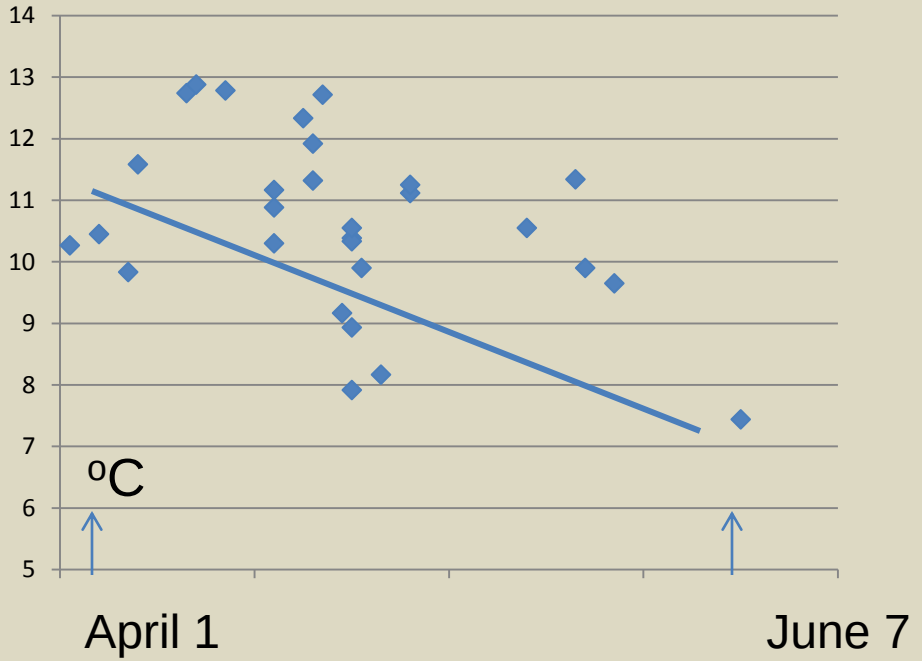
initiation of spawning by resident invertebrates and fishes in spring



Blue box: range in the timing and temperature for the **first occurrence** of larvae of resident shrimps, crabs, and fishes (some listed) during spring

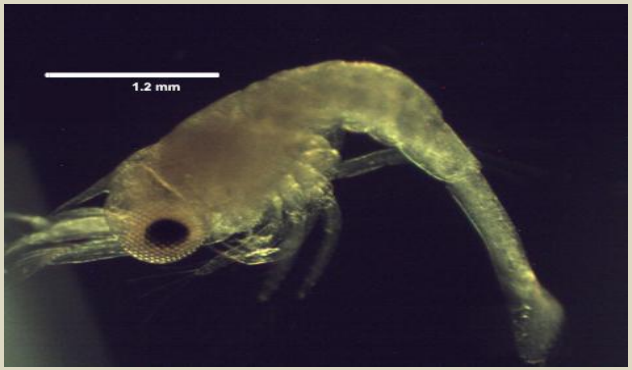
Upogebia affinis mud shrimp larvae

Relationship between date of 1st occurrence and mean temperature during two previous months:
r = -0.63, p < 0.0001

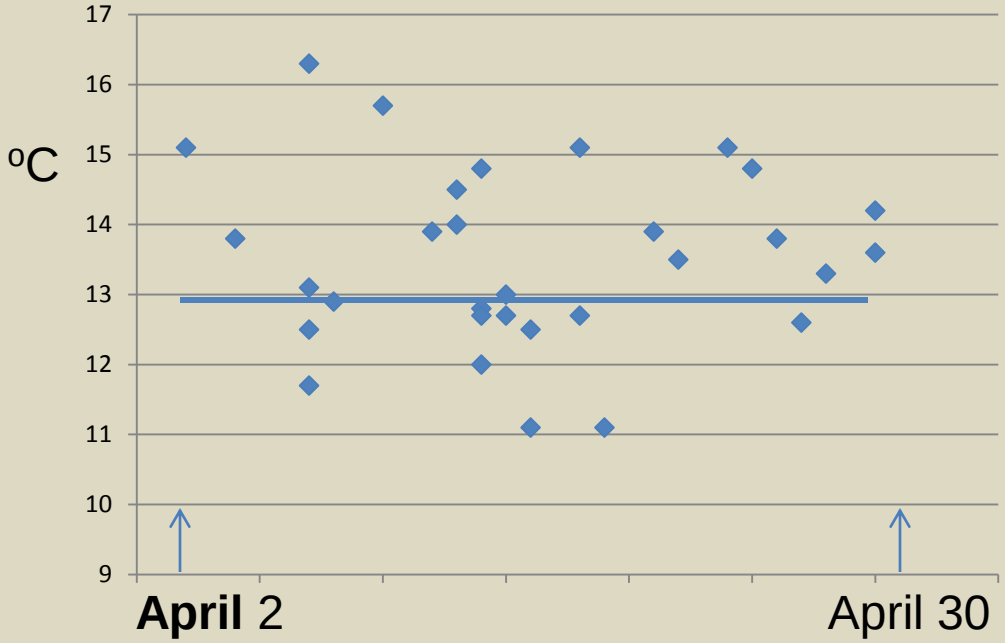


The <u>warmer</u> the winter temperatures, the <u>earlier</u> the larvae first occur

Palaemonetes pugio (and *P. vulgaris*) grass shrimp larvae



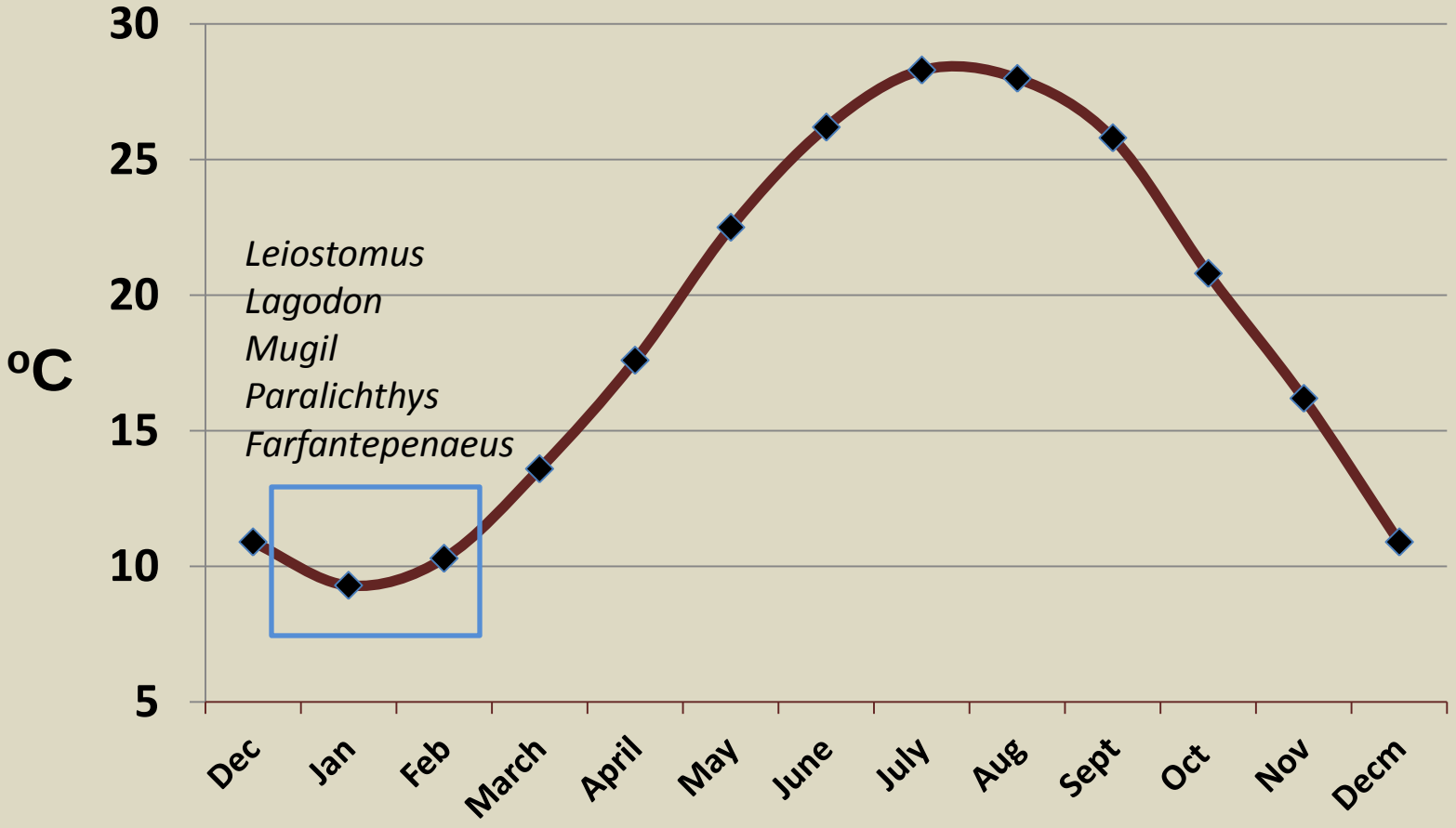
No relationship between date of 1st occurrence and mean temperature during two previous months:



Late winter temperatures <u>do not appear to influence</u> the timing of 1st occurrence.

Mean monthly water temperature for the period 1981-2010

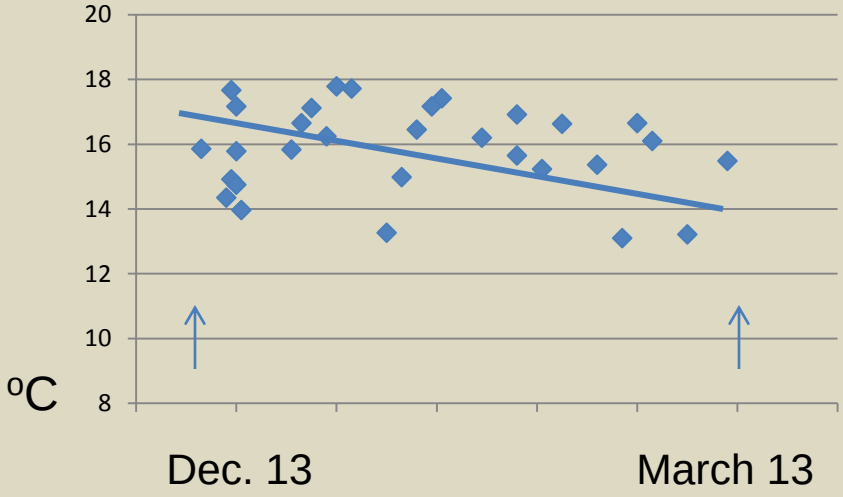
fall-winter larval ingress of transient species from the ocean



Blue box: range in the timing and temperature for the **first occurrence** of larvae of transient shrimps and fishes (some listed) during winter

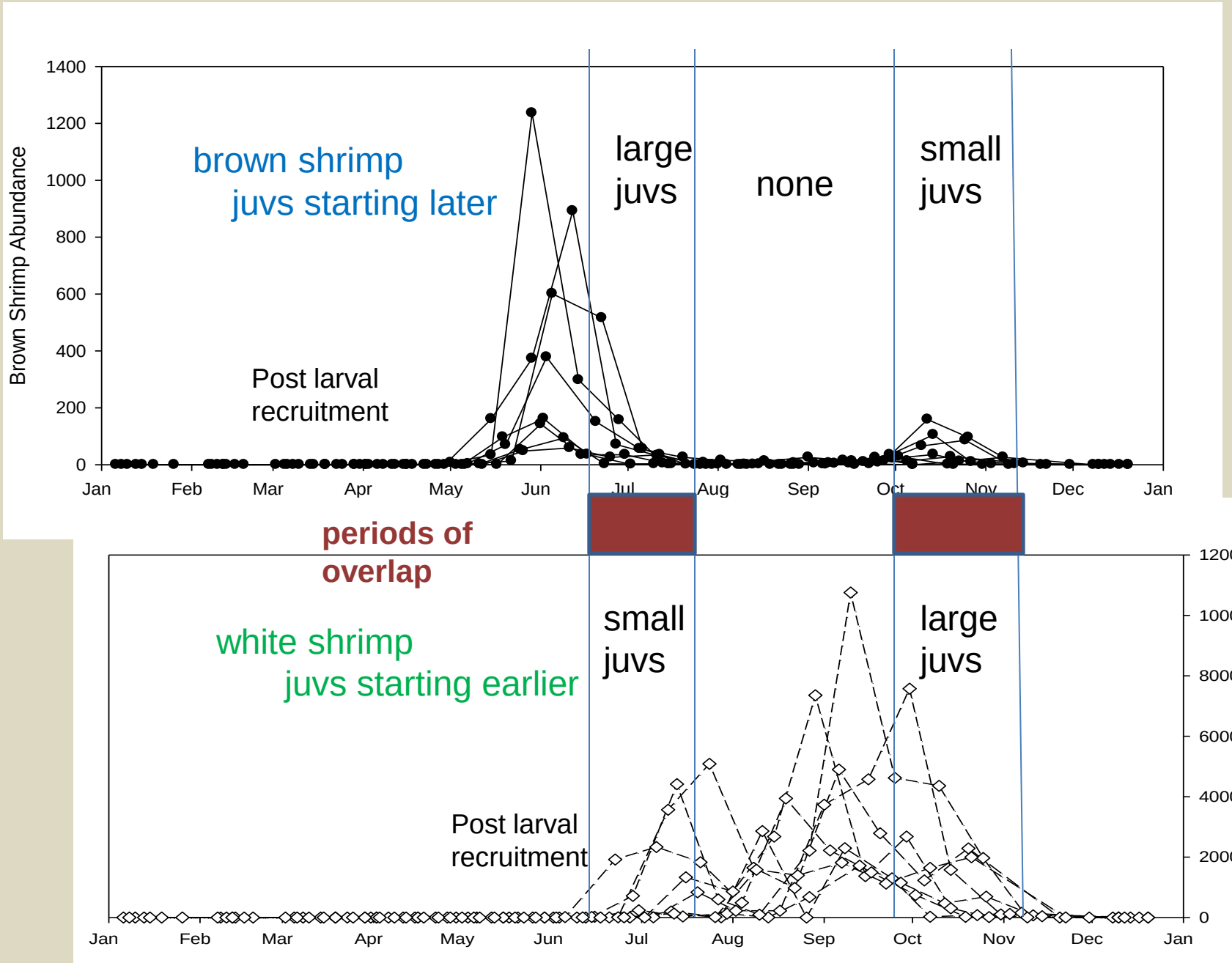
Farfantepeneus aztecus
brown shrimp postlarvae

Relationship between date of 1st occurrence and mean temperature during two previous months:
r = -0.37, p< 0.001

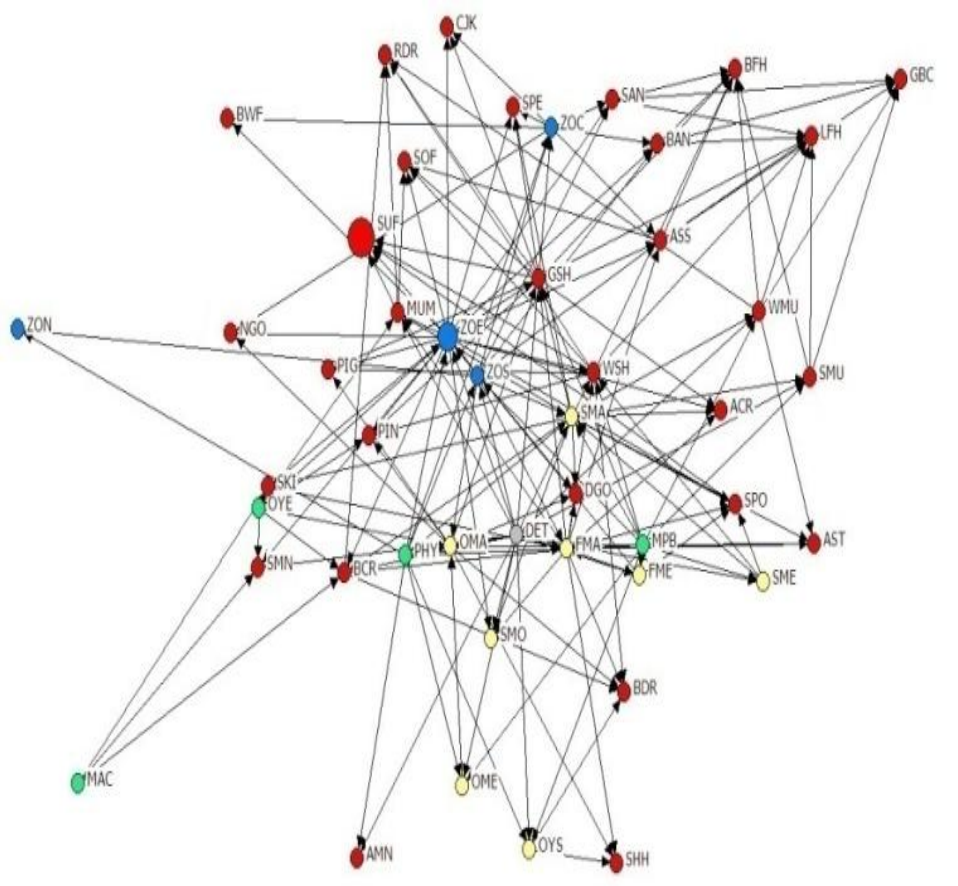


The <u>warmer</u> the late fall temperatures, the <u>earlier</u> the date of 1st occurrence

Timing of overlapping use of the ‘nursery’ habitat



Phenological changes could have consequences for community and trophic structure, secondary productivity, and ecosystem services.



…… and for fisheries?

Long-term changes in fish, shrimp, and crab populations in an intertidal salt marsh basin: abundance, growth, production, and species composition

Oyster Landing Basin, North Inlet, SC

1984-2002 Low Tide sampling

- seine a pool in the intertidal creek

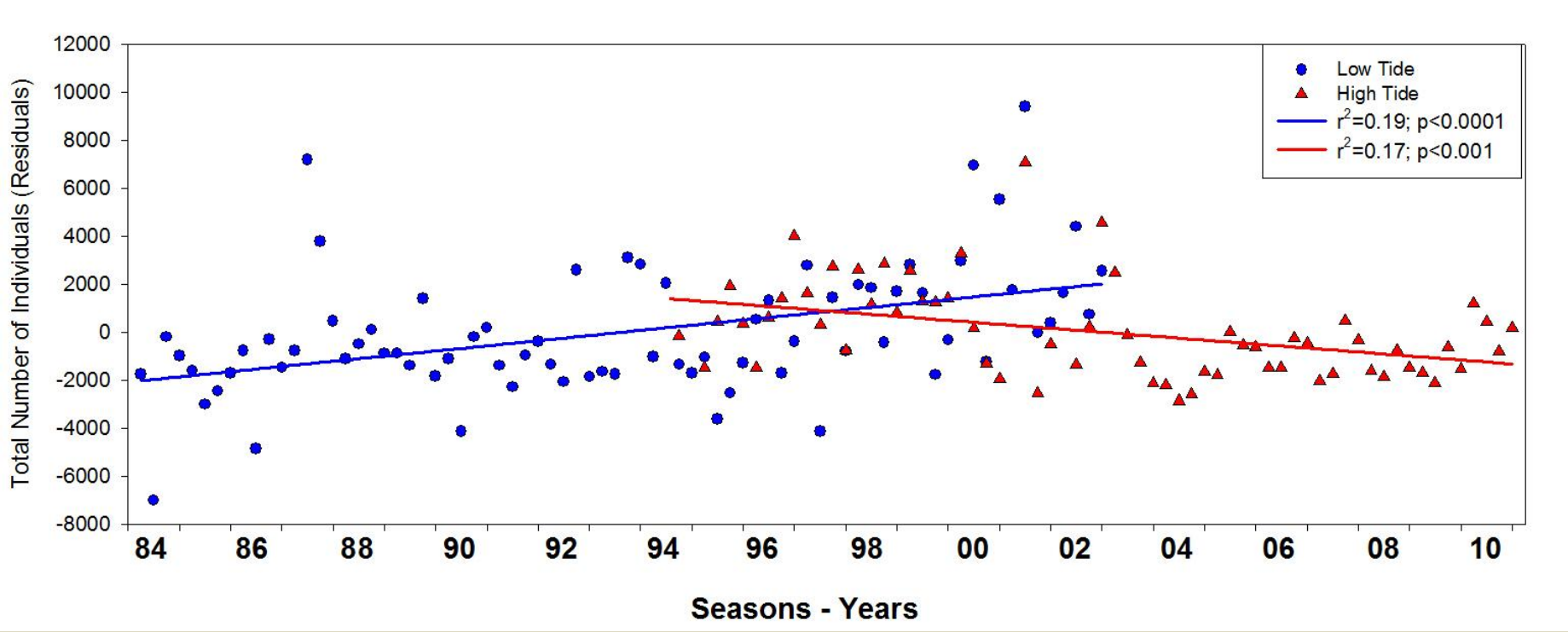
1994-2011 High Tide sampling

- block net set down-tide of an enclosed area of flooded marsh

Oyster Landing: mean seasonal abundances of total nekton

Low tide collections 1984-2002: increasing trend (blue line)

High tide collections 1995-2011: decreasing trend (red line)

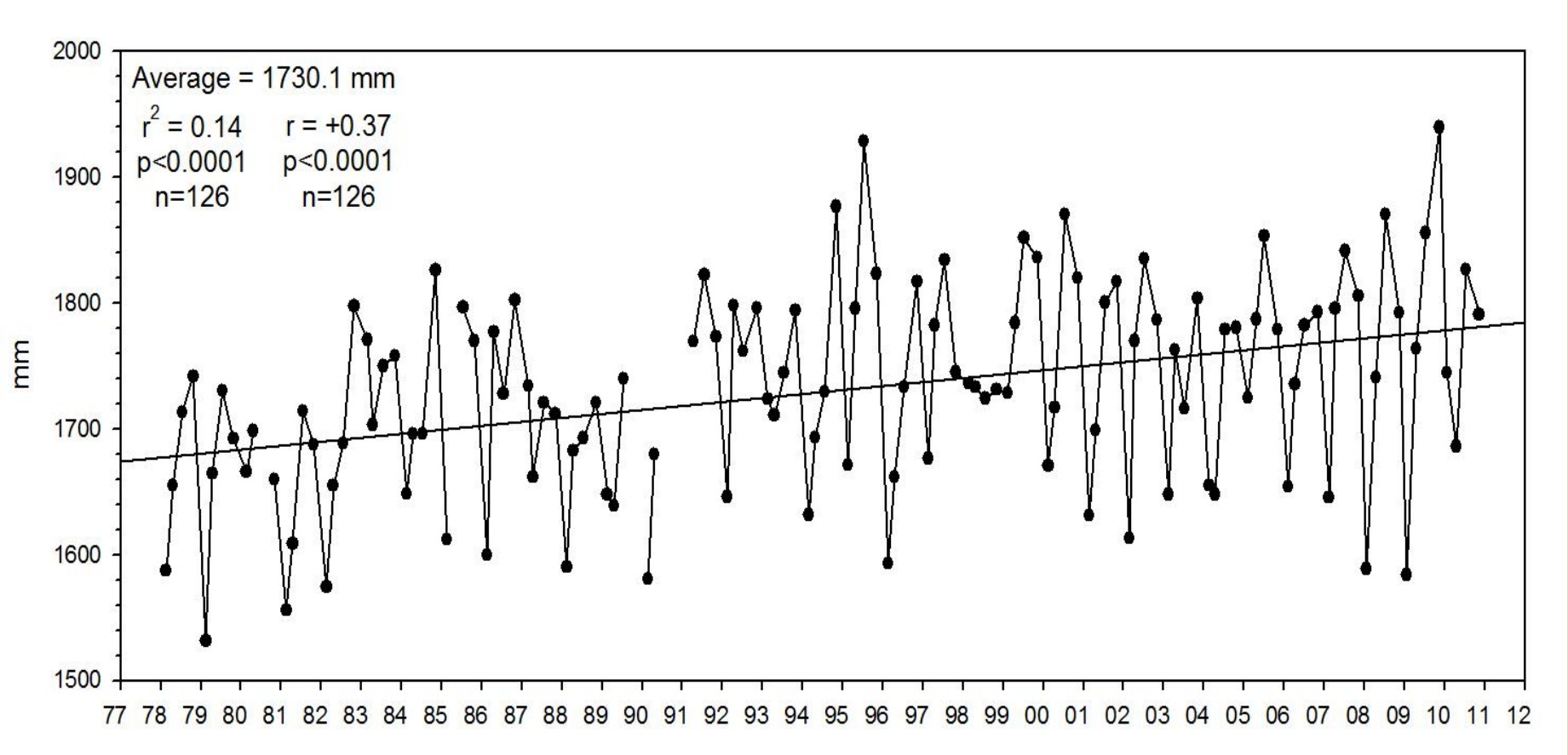


Changes in nekton 1994-2011?

- **reductions in abundance on the order of 50%**
- **no changes in measures of community composition**
- **indicates a downsizing of assemblage using the basin**
- **raises the questions as to whether the capacity or nursery function has diminished**

Oyster Landing Basin, North Inlet estuary, SC : seasonal mean Sea Level 1978-2010

Increasing trend: ~ 100 mm (~3.9 inches) in past 30 years

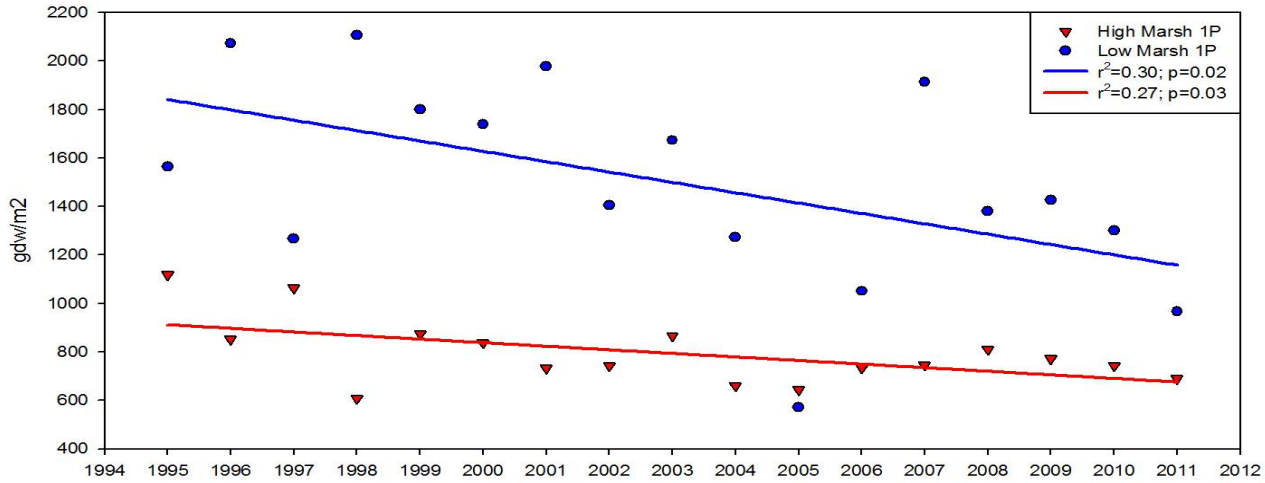


Data from Charleston Harbor NOAA station, highly correlated with NOAA OL tide gauge

Tidal marshes and sea level: to keep from being drowned, marshes have to accumulate enough sediment to keep up with sea level rise.

The current prediction is that most coastal marshes will not be able to keep up and much of North Inlet will be a lagoon within 50 years.

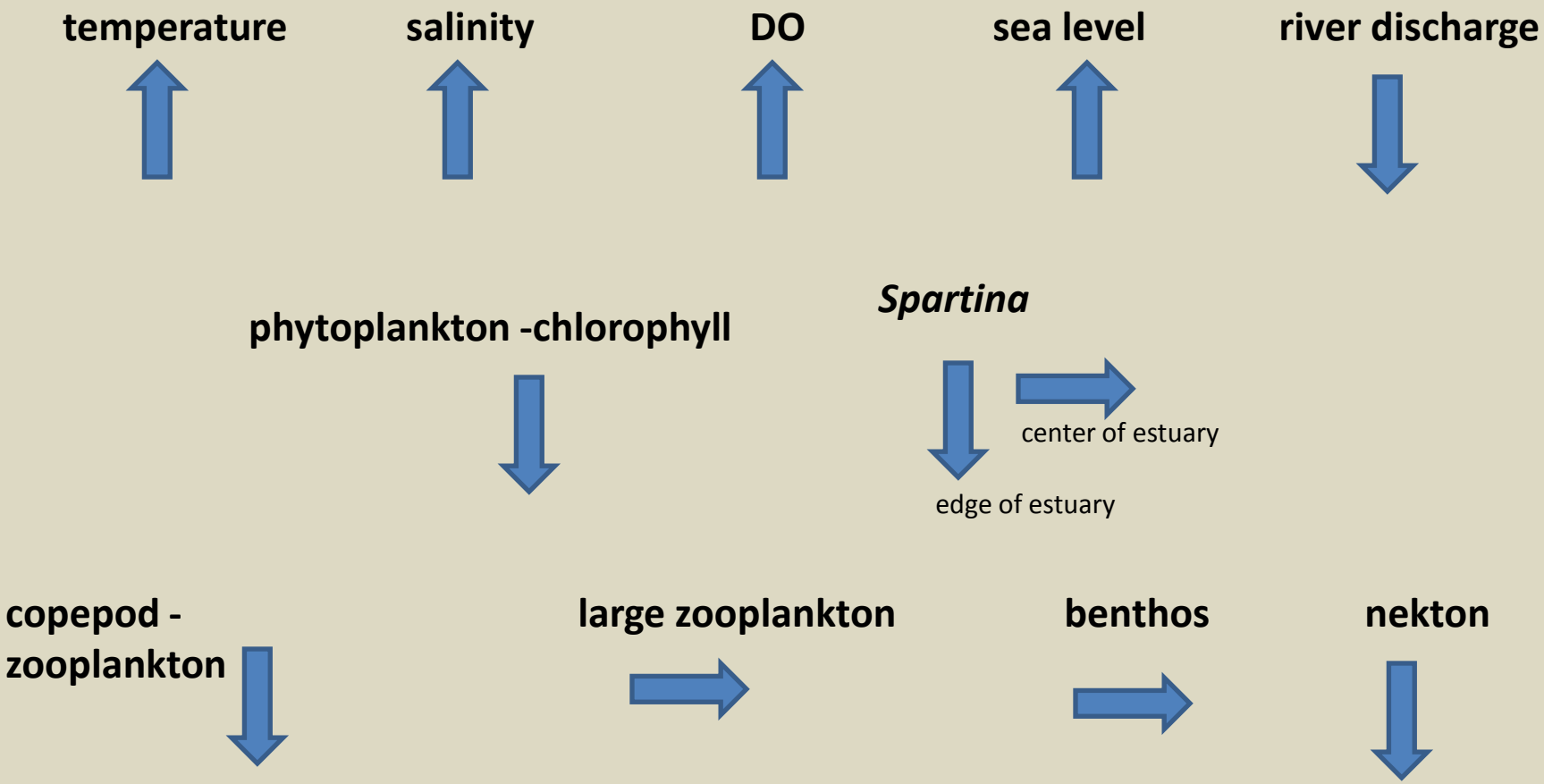
Spartina production; high marsh (red) and low marsh (blue)
Oyster Landing Basin 1995-2011



http://links.baruch.sc.edu/Data/NISpartina/data/Spartina.data.html

Is there a relationship between marsh production and nekton in Oyster Landing basin?
significant positive correlation: r= 0.52, p=0.04

North Inlet estuary 1990- 2010: simple summary of changes observed for some environmental variables and biota



Is there evidence of climate variability and effects on faunal assemblages from long-term time series measurements in North Inlet estuary, SC?

Short answer is yes

We have observed
- changes in environmental conditions in the estuary
- decreases in animal abundance and primary production
- shifts in the timing of reproduction and migration of some taxa

At this point, the composition of the assemblages and structure of the food web do not appear to have changed much

However, we have
-identified relationships between climate (events/patterns) and fauna
-recognized that the same mechanisms that have affected changes in community and trophic structure elsewhere are in place

We can expect changes in the ecology of South Carolina estuaries in the decades ahead.

Acknowledgements:

Thanks to the more than 150 investigators, technical staff , and students who participated in field collections, experiments, sample analysis, data management, and/or interpretation of results over the past 30 years.

And to: Paul Kenny, Tracy Buck, Amy Willman, Erik Smith and many other past and present staff of the Baruch Institute USC

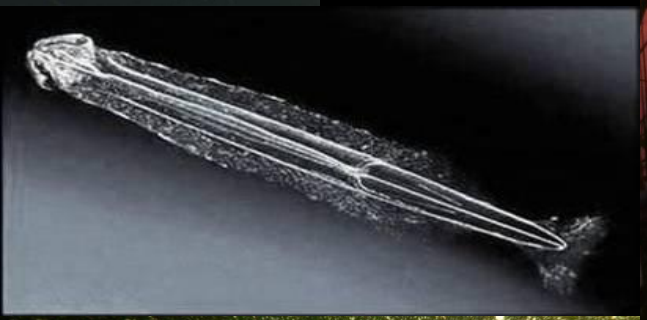
Funding support for long- term time series was primarily from:

NSF : North Inlet Long-Term Ecological Research Program (1981-1992)

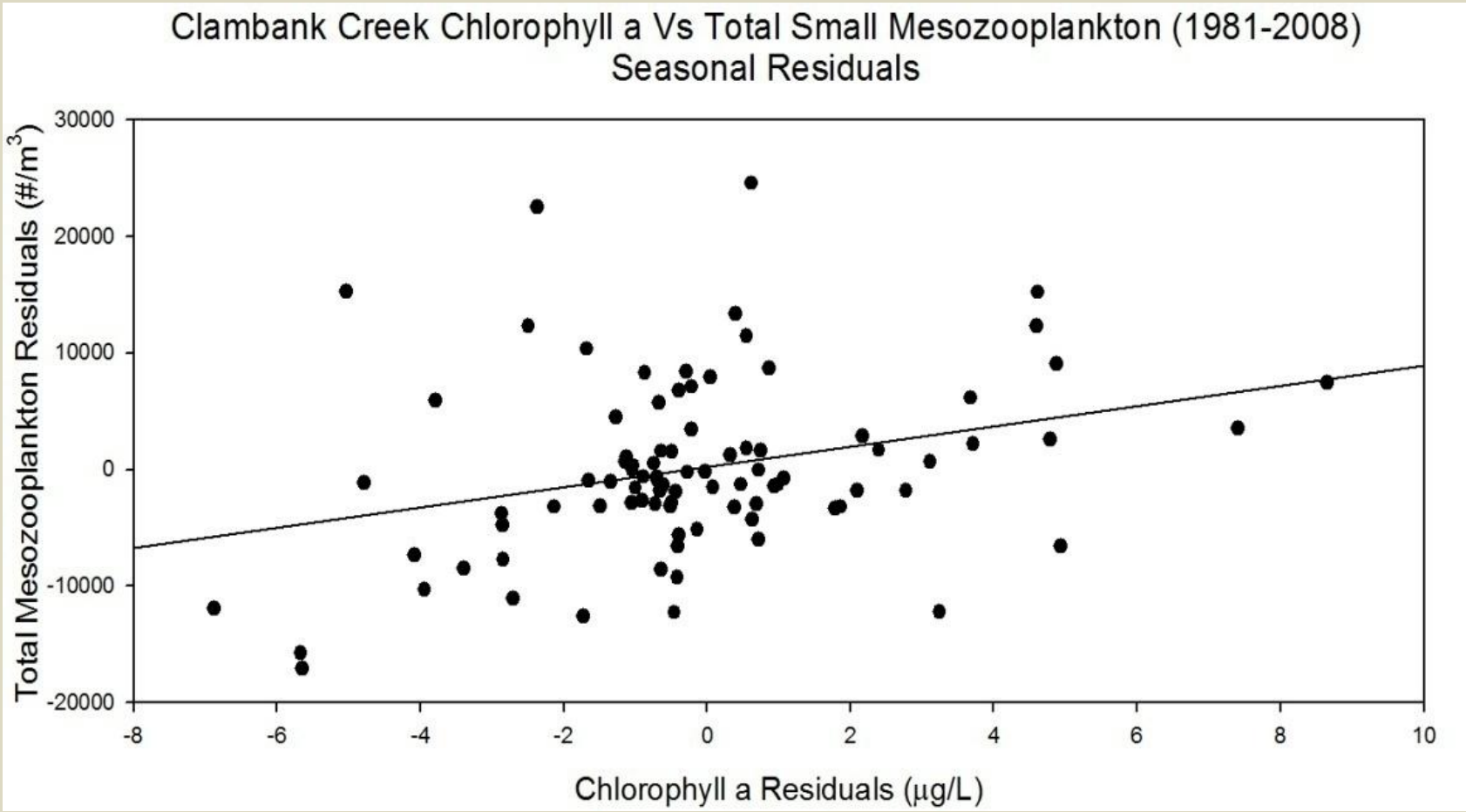
NOAA : North Inlet- Winyah Bay National Estuarine Research Reserve (1993 – present)

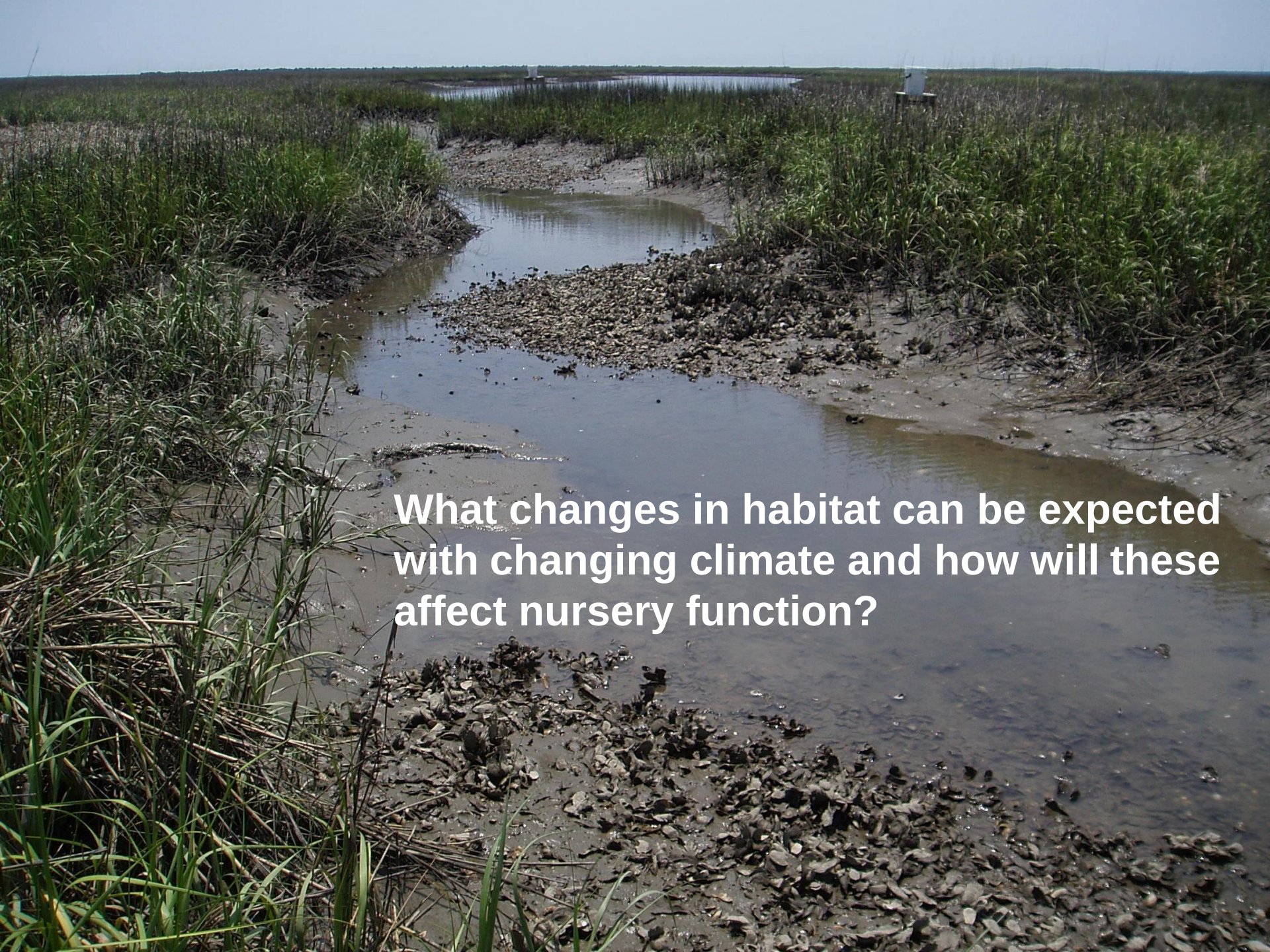
data and more available at:

www.cas.sc.edu/baruch/



small zooplankton abundance is correlated with chlorophyll concentration r = 0.29 p = 0.005




What changes in habitat can be expected with changing climate and how will these affect nursery function?